EVALUATION OF NEARSHORE BATHYMETRY MANDALAY BEACH, VENTURA COUNTY, CALIFORNIA

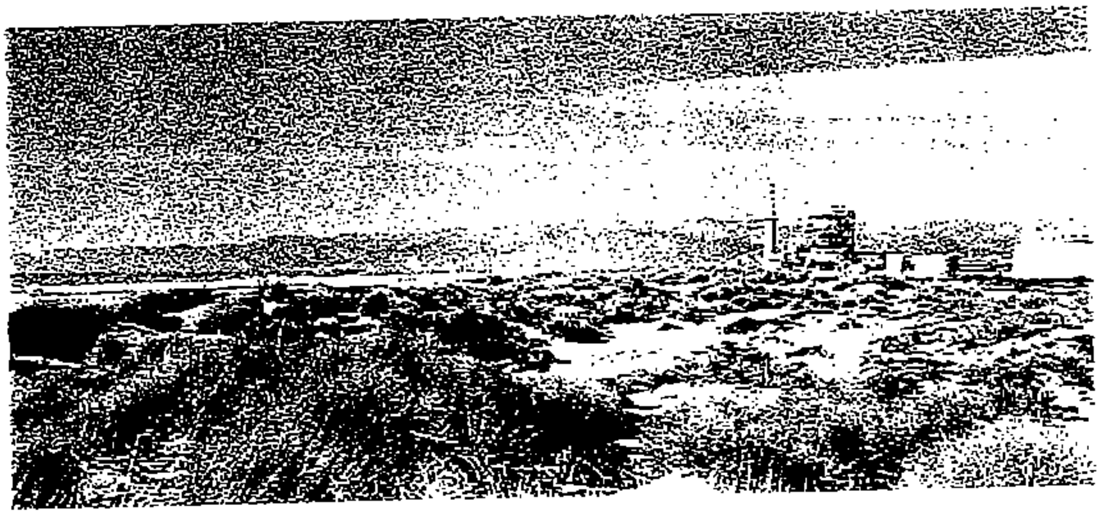

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report evaluates offshore bathymetry changes off Mandalay Beach. Mandalay Beach is located in Ventura County, California, between the Ventura and Channel Islands Harbors. It is located near the southern end of the Santa Barbara Littoral Cell, which extends from Point Conception to Hueneme Submarine Canyon (Inman and Frautschy, 1966).

Southern California Edison Company (SCE) requested this study to assist in development of a viable plan to permanently abandon and/or remove the Mandalay marine pipeline. The pipeline is a single, 24-inch (0.61 m) diameter seamless pipeline extending 4,950 feet (1509 m) offshore at a bearing of 250 degrees. The pipeline was formerly used to transport fuel to the Mandalay Generating Station from offshore oil tankers. A recent study by Ecosystems Management Associates, Inc. (2000) showed that the pipeline, anchors and chains for fuel supply ships are presently buried beneath the sandy floor.

This study is based on 1) historical beach and bathymetric studies, 2) recent survey data, and 3) beach profiles taken as part of this study. The historical bathymetry data in the vicinity of Mandalay Beach dates back to 1933.

Ventura and Santa Clara Rivers are the primary natural source of sand for the Ventura County shoreline. Since 1948, when dams were first built in this area, total drainage areas have been reduced by about one-third (Inman, 1976). Ventura and Channel Islands Harbors trap longshore sediment drift. Sand trapped in Ventura Harbor is routinely dredged and placed on McGrath State Beach, upcoast of Mandalay Beach. Once every two years entrapped sand at Channel Islands Harbor is also dredged.

The total sand input to the Santa Barbara Littoral Cell at Mandalay Beach is estimated to be 1,230,000 yd^3/yr (941,000 m^3/yr). The longshore transport rate at Mandalay Beach is 1,250,000 yd^3/yr (946,000 m^3/yr). Therefore, the quantities of sand being supplied to the cell nearly balance the longshore transport and ultimate losses from the cell, down the Hueneme Submarine Canyon (Inman, 1976). Therefore, Mandalay Beach sustains a relatively stable shoreline position under normal and long-term conditions, but undergoes temporary beach erosion episodes with periodic occurrence of high waves. Seasonal and inter-annual fluctuations in the Mandalay Beach mean-lower-low-water (MLLW) shoreline position can exceed 200 feet in the vicinity of the pipeline alignment.

The long-term trend of the shoreline position at Mandalay Beach has been one of slight erosion from 1933 to 1977 and one of stability or modest advancement since 1987. This is related to variation in river discharge sand quantities due to wet and dry weather time periods. Although the winter profile bar in the area can experience changes due to winter storms, elevation changes in the offshore portion of the profile at water depths of 30 ft or greater are found to be small. Bathymetry changes over the past 67 years (1933 to 2000) at the offshore area beyond 1700-1800 ft (548 m) from the shoreline were about ±2 feet (± 0.6 m).

EVALUATION OF NEARSHORE BATHYMETRY MANDALAY BEACH, VENTURA COUNTY, CALIFORNIA

1.0 INTRODUCTION

This report addresses the oceanographic conditions, coastal processes and nearshore changes in bathymetry off Mandalay Beach, located in Ventura County, California. The objective of this study is to quantify nearshore bathymetric changes offshore of the Mandalay Generating Station.

Southern California Edison Company (SCE) requested this study to assist in developing a viable plan to permanently abandon/remove the Mandalay marine fuel oil supply pipeline. The Mandalay pipeline off-loading facility consists of a submerged marine oil supply pipeline and offshore ship-mooring anchors and chains. A recent bathymetric survey conducted by EcoSystems Management Associates (2000) showed that the pipeline, anchors, and chains are presently buried below the area's sandy sea floor.

This study is based on historical studies and recent beach profiles; and bathymetric, side-scan, sub-bottom profile surveys. The study provides: 1) evaluation of historical beach and sea floor elevation changes in the vicinity of the pipeline; and 2) description of oceanographic conditions, sand transport, river sand supply, and human intervention in the region. The study shows that changes in the offshore bathymetry at 30 ft (9.7 m) of water or greater over the next 67 years are estimated to be small and within 2 to 3 ft..

2.0 PROJECT LOCATION/SITE DESCRIPTION

Mandalay Beach is located in Ventura County, California, between the cities of Ventura and Oxnard. It is approximately 3 miles (4.8 km) west of the City of Oxnard, and about 0.5 mile (0.8 km) north of Fifth Avenue (Figure 1). The Ventura Harbor is 2.5 miles (4 km) to the north, and Channel Islands Harbor is 3 miles (4.8 km) south of Mandalay Beach. The most significant natural feature in this region is the Santa Clara River mouth, which lies directly south of Ventura Harbor.

Mandalay Beach is characterized as a straight sandy beach with a series of intact low-lying protective dunes on the inland side (Figure 2). It is part of the 20-square-mile Port Hueneme dunes. The offshore (mainland) shelf at Mandalay Beach is narrow, about 5 to 6 miles (8-9.6 km) wide. Mandalay Beach is about 5 miles (8 km) north of the Hueneme Submarine Canyon (Figure 1).

Mandalay Beach is known for strong nearshore currents and significant longshore sand movement. The first SCE pipeline construction site survey (Pafford & Associates, 1957) noted strong bottom currents toward shore. Also, a letter prepared during a 1972 upgrade of the pipeline mooring anchor system (to accommodate larger oil tankers) stated, "Our Mooring Masters have experienced at Mandalay the strongest currents of any terminal on the coast" (Chevron USA, 1972).

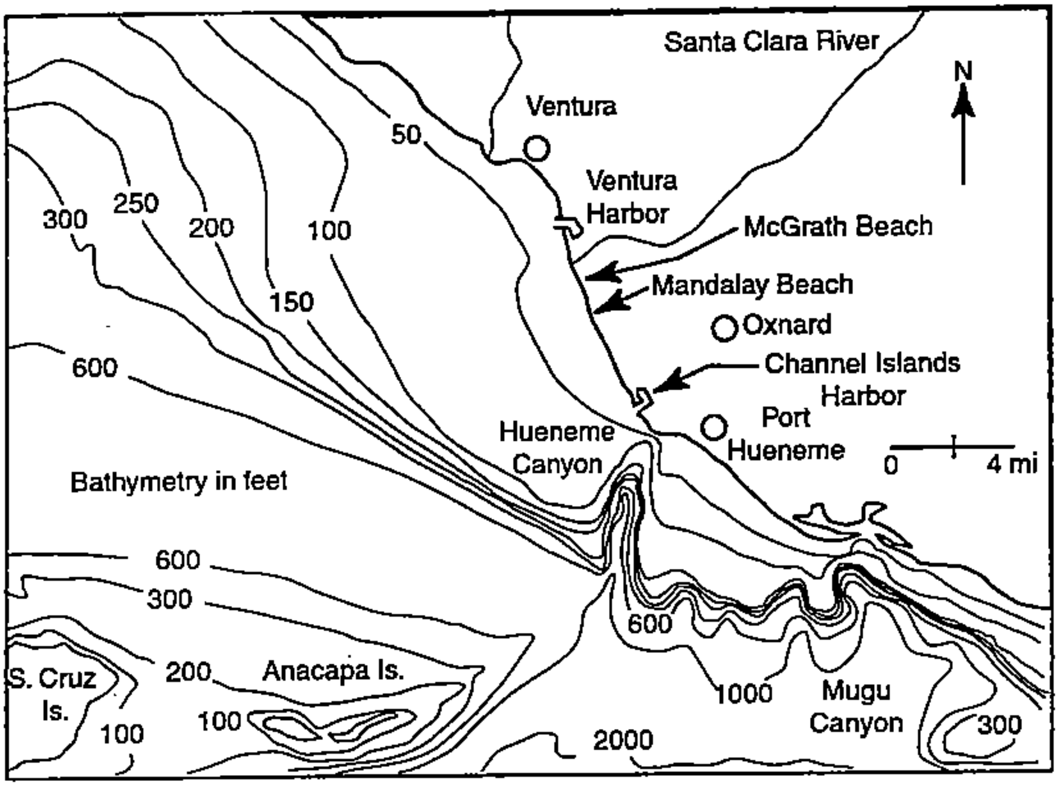

Figure 1. Location map of Mandalay Beach (adopted from Intersea Research Corp, 1973).

Figure 2. Sand Dunes at Mandalay Beach (phot graphs taken on February 2, 2000).

3.0 DESCRIPTION AND HISTORY OF THE PIPELINE

The SCE Mandalay marine pipeline is located adjacent to the southeast side of the Reliant Energy Company Mandalay Generating Station property. The Mandalay pipeline is a single, 24-inch (0.61 m) diameter seamless marine pipeline extending 4,950 feet (1509 m) at a bearing of 250 degrees from the shoreline terminal and storage tank facility located behind the natural beach dunes (Figure 3). The pipeline was used to off-load oil from ships. The seaward terminus of the pipeline is located at an approximate water depth of 45 ft (13.7 m).

The Mandalay pipeline was installed in 1958 and was upgraded with heavier mooring anchors and new ship transfer flex hose at the seaward terminus in 1972. The system has been officially in "caretaker" status since February 1993. In 1992, the offshore terminus ship-mooring buoys and most of the anchor chains were removed from the site.

A recent bathymetric, sub-bottom sonar, magnetometer, and beach elevation survey conducted by EcoSystems Management Associates (2000) showed that the pipe was buried. The sonar and magnetometer aspects of the survey covered the area between 12 ft and 48 ft (3.7 to 14.6 m water depth). Sand thickness on the top of the pipe varied between 2 and 4 ft (0.61 and 1.22 m). During the survey, various buried objects were identified. Some of these objects could be the ship-mooring buoy anchors. Figure 4 gives the burial depth for the pipe and the various identified objects and shows the historical positions of the mooring anchors. From Figure 4 one may conclude that the anchors are likely buried under the sea bottom by 3 ft (0.91 m).

4.0 HUMAN INTERVENTION SURROUNDING MANDALAY BEACH

4.1 DAMS

Prior to 1948 there were no dams on either the Ventura or Santa Clara River drainage basins. However, since 1948 the total drainage areas of these basins have been reduced by about one-third with the construction of the Matilija, Casitas, and Santa Felicia dams. Dams and debris basins retard the transport of sediments to the shoreline. Therefore construction of these water conservation and flood control facilities has probably reduced the natural supply of sediments available to the area's beaches.

4.2 HARBORS, JETTIES AND SAND TRAPS

Mandalay Beach is located between Ventura Harbor and Channel Islands Harbor. Ventura Harbor and the Channel Islands Harbor were built in 1964 and 1960, respectively. Both harbors trap the longshore sediment drift. Sand trapped in Ventura Harbor is routinely dredged and placed on McGrath State Beach, which is just upcoast of Mandalay Beach. A study conducted by U. S. Army Corps of Engineers (ACOE) (1989) showed that the routine disposal of the sand on McGrath State Beach has had no noticeable effect, either positive or negative, on the beaches downcoast of the Santa Clara River.

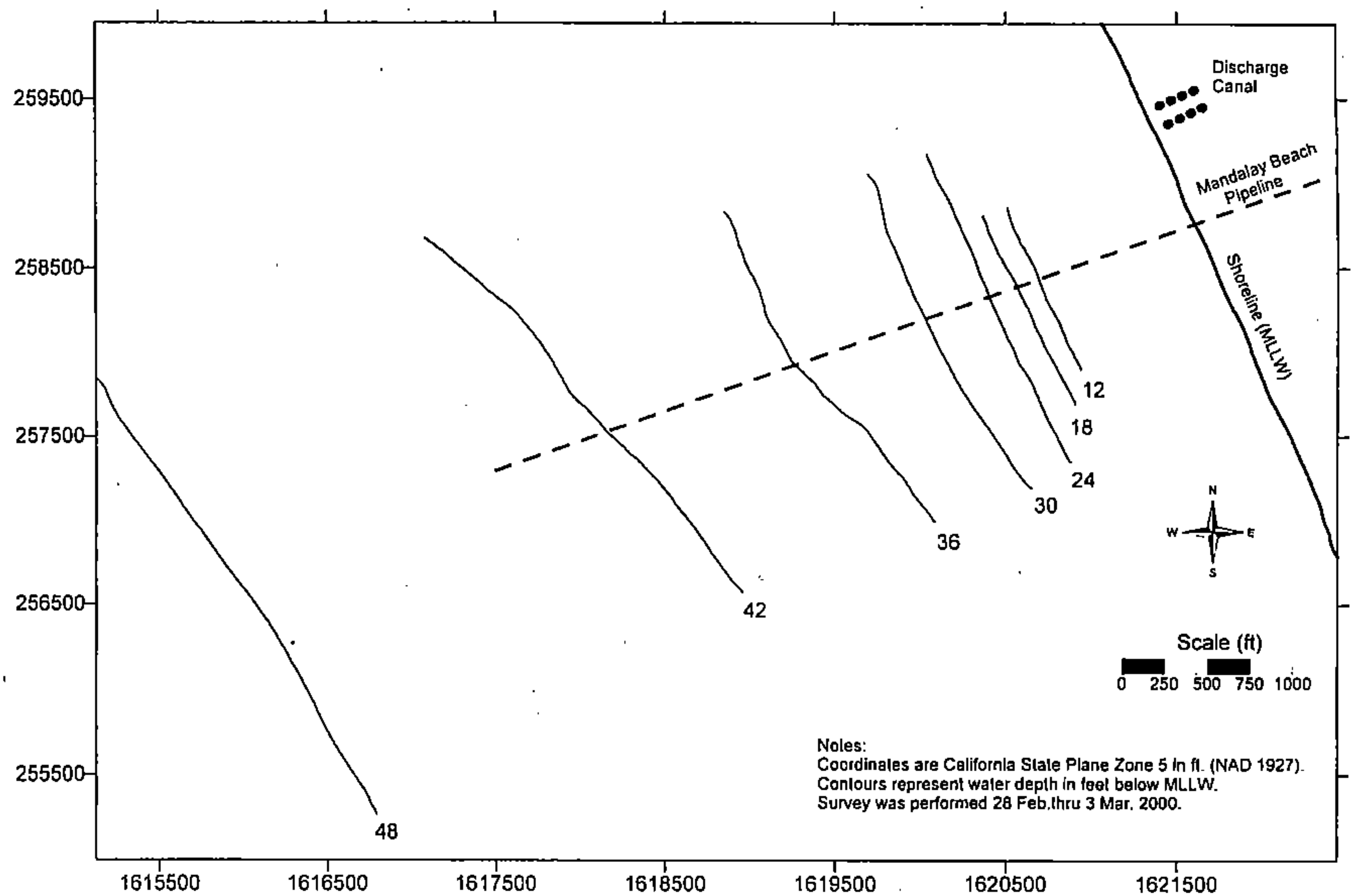

Figure 3. Southern California Edison (SCE) Mandalay marine pipeline. Depth contours obtained from EcoSystems (2000).

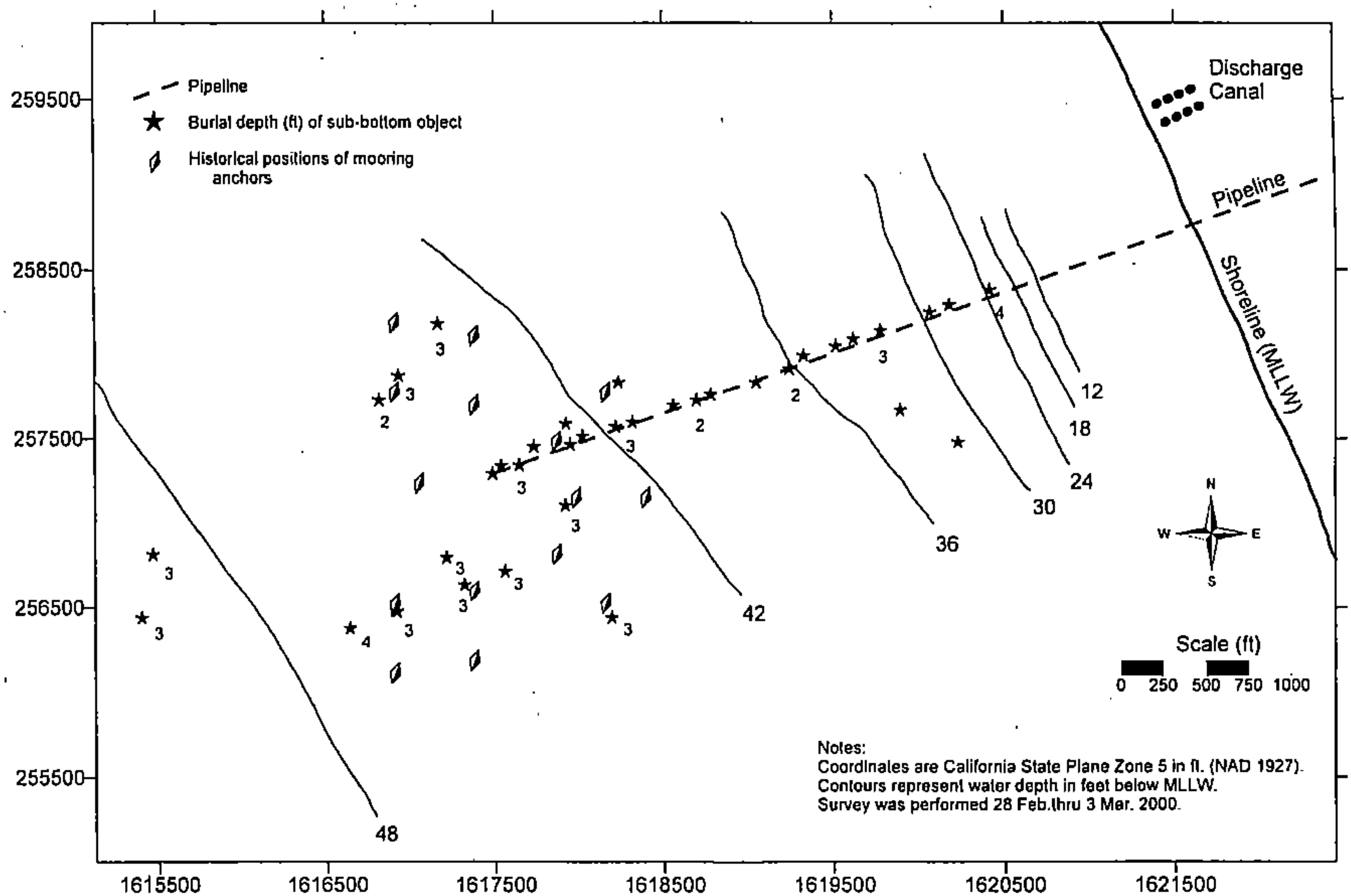

Figure 4. **Map showing burial depth of the pipeline and objects identified during 3 March 2000 sub-bottom survey, and the historical positions of anchors in the area (Eco-Systems, 2000).**

5.0 CLIMATIC AND OCEANOGRAPHIC INFLUENCES AT MANDALAY BEACH

5.1 CLIMATE INFLUENCES

Southern California lies within a climatic regime broadly defined as Mediterranean, which is characterized by short, mild winters and warm, dry summers. The climate is influenced mainly by the East Pacific high-pressure area, whose center lies to the northwest, between Hawaii and Alaska. In summer, this pressure system intensifies, resulting in mild, dry weather and a blockage of storms. In winter, the high pressure area weakens and moves to the south and west. Cold fronts occasionally cross the southern California coast resulting in cooler weather and occasional rain.

Rainfall in southern California undergoes dry and wet cycles. The time period from 1946 to 1977 was a dry time period and the time period from 1978 to present is a wet time period (Elwany et al. 1995). The river flows vary considerably from year to year relative to the amount of precipitation (see Figure 5). Drought conditions in the area's watersheds have had an adverse effect on the supply of beach-building sediments reaching the coast.

Occasional floods of considerable magnitude bring large amounts of sediment to the beach. In January and February of 1969 such a flood took place on the Santa Clara River. The highest river flow rates ever recorded deposited 44,000,000 yds^3 (34 million m^3) of sand at the river mouth. This deposition formed a delta at the mouth which extended 2,000 ft (610 m) seaward of the shoreline. The sand contributed from the 1969 flood has been estimated to be equivalent to a 22-year annual contribution from the river (Inman, 1976).

5.2 WAVES

Longshore littoral currents are generated by waves breaking at an angle to the shoreline. The magnitude of these currents is dependent upon the incoming wave energy, angle of wave approach, and shoreline orientation. The Mandalay Beach area lies at the east end of the Santa Barbara Channel (Figure 6). The Mandalay area is protected from southern swells by the islands and its west-facing mainland orientation (266° - 287°). Therefore, most of the wave energy encountered by Mandalay Beach comes from the west. In the area's open ocean, the predominant wave energy comes from the northwest as locally generated waves and swells are generated in the North Pacific. Northern hemisphere swells are most common during the winter months due to the strong winds associated with the seasonal cyclonic storms in the North Pacific Ocean. Swell from southerly directions can be expected 30-50% of the time from April to September (Intersea Research, 1973). These waves are generated by storms in the South Pacific Ocean or by hurricanes located off the coast of Mexico. Short period waves that are generated between the Channel Islands and the mainland can approach the Mandalay Beach area from any direction ranging from southeast to northwest.

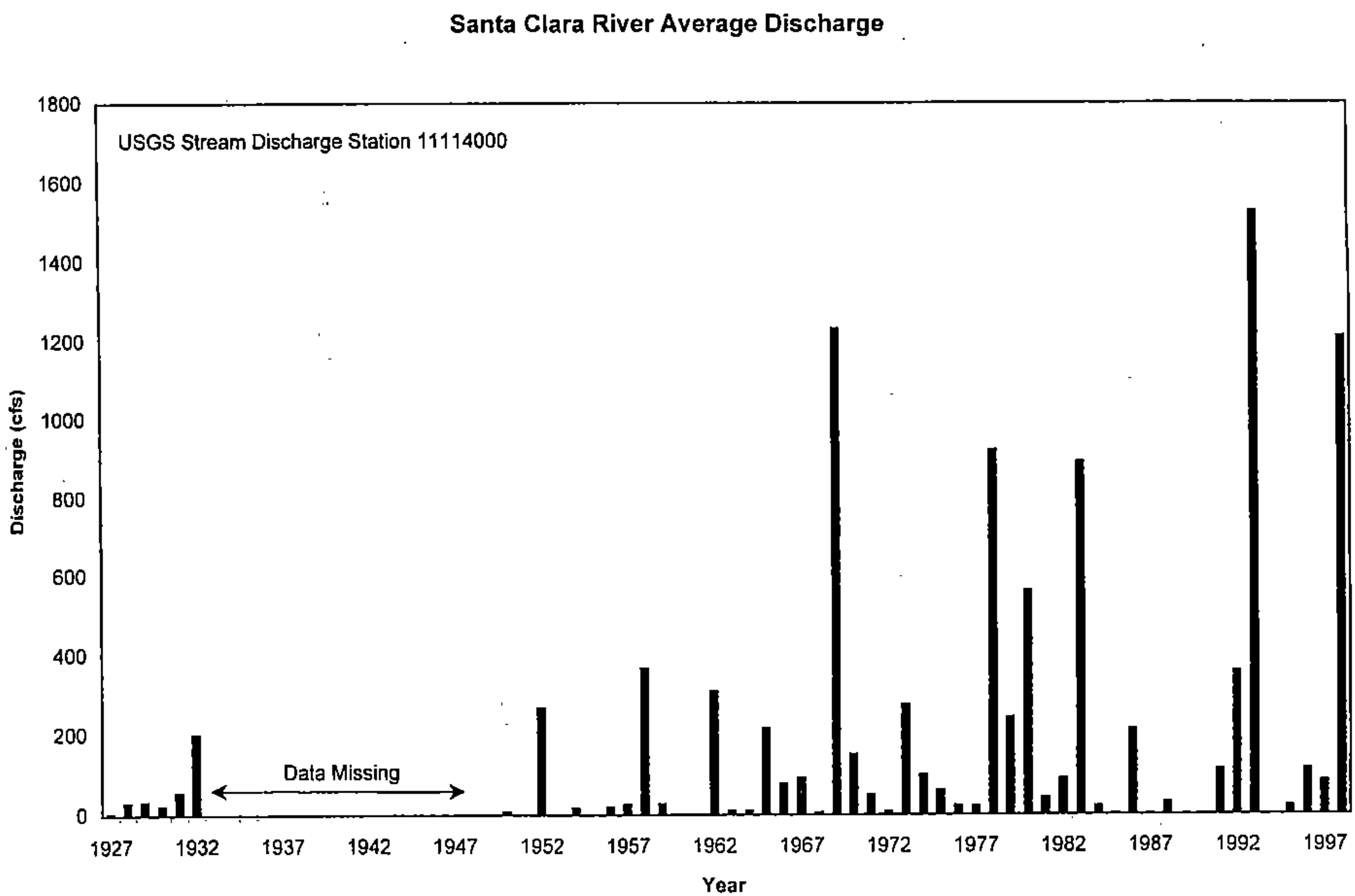

Figure 5. Santa Clara daily average discharge from 1927 to 1998. Measurements made by USGS at Station 11114000.

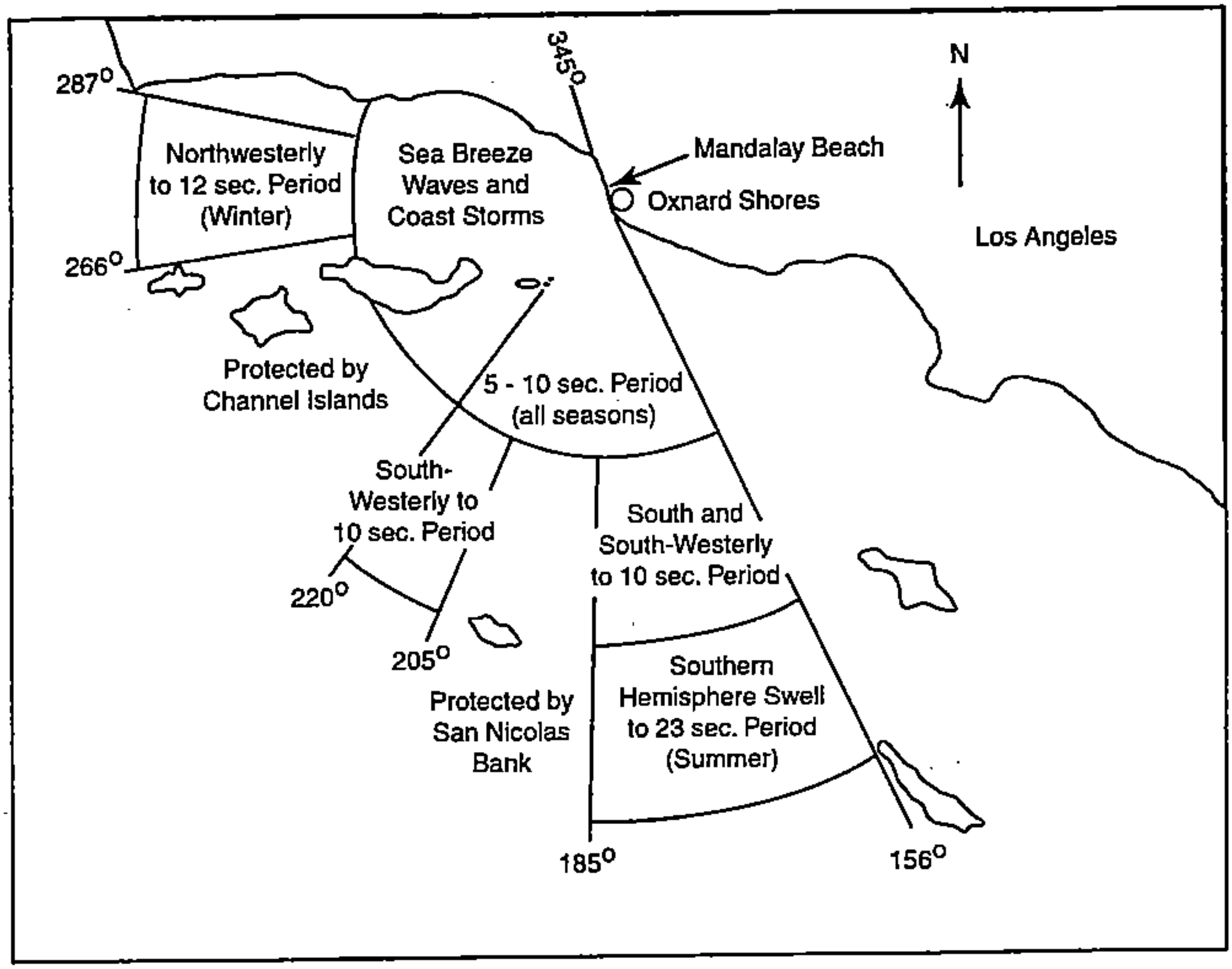

Figure 6. Wave Characteristics for Mandalay, from Inman (1976).

From spring through fall of each year and through most of each winter, the track of North Pacific storms is far enough north such that Ventura County beaches are sheltered from ocean swells by Point Conception. Only on rare occasions does the storm track migrate far enough south to expose Ventura County to these swells; on these occasions, breakers of 6 to 8 feet (1.8 to 2.4 m) have been observed. During the 1977-78 winter storms, average high surf of 5 to 6 feet (1.5 to 1.8 m) was experienced. Maximum daily sets of 10 feet (3 m), and up to occasional 15-foot (4.6 m) surf, were reported. Some of these storm conditions coincided with the highest winter tides of +7.0' feet (2.1 m). Although the maximum reported surf of 12 to 15 feet (3.7 to 4.6 m) on southern California beaches during winter storms is not considered an extremely rare event, falling perhaps into the 5- to 15-year return period category, the accumulative effects of repeated high surf over long periods of time, such as experienced during the 1977-78 and 1982-3 time frame, were rare.

Winter storms have caused significant damage in the Oxnard Shores area just downcoast from Mandalay Beach since the 1930's (Noble, 1989). Winter storms in 1937, 1939, 1960, 1963, 1965, 1969, 1971, 1978, 1983, 1988, 1995, and 1997-98 were especially noteworthy in causing widespread erosion along Ventura County and in certain specific areas such as Oxnard Shores.

6.0 SAND BUDGET

6.1 SEDIMENT SOURCES

The Ventura and Santa Clara River mouths are prominent features along the Ventura coastline and have historically provided sediment to Mandalay Beach as well as to the rest of the coastline. The Santa Clara River is an intermittent stream, flowing mostly during the rainy season from November to March. The Ventura River is an interrupted watercourse with portions of both the upper and lower river maintaining perennial surface flow. The Ventura and Santa Clara Rivers have drainage areas of 226 and 1,628 square miles (585 and 4217 km^2), respectively and annually discharge about 130,800 and 654,000 yd^3 (100,062 and 500,310 m^3) of sand, respectively (USACOE, 1980).

The Ventura and Santa Clara Rivers are the primary sources of sand nourishment for the Ventura County shoreline. The USACOE, in a joint venture with the Ventura County Flood Control District, studied the influence of these rivers on the regional beaches and nearshore bathymetric regime (USACOE, 1980). The study results indicated that the Ventura and Santa Clara Rivers provide a major sediment supply to the coastline, but that long periods with small quantities of sediment discharged from the rivers can cause continuous sand starvation and beach erosion to the Ventura County coastline. Sediment deposited in the river mouth deltas may take years to reach the downcoast shoreline, depending upon wave actions. High tides and large wave action have immediate and severe impacts on the movement of coastal sand deposits.

6.2 THE LITTORAL CELL

Mandalay Beach is located near the southern end of the Santa Barbara Littoral Cell which extends from Point Conception to Hueneme Submarine Canyon (Inman and Frautschy, 1966). In general, the southern California coastal area is divided into five distinct sedimentation compartments known as littoral cells (Figure 7). The natural sources of sand for the Santa Barbara Littoral Cell are the Ventura and Santa Clara Rivers, which are 2 miles (3 km) and 4 miles (6 km) north or up-drift of Mandalay Beach. Since 1948, when dams were first built in this area, total drainage areas have been reduced by about one-third (Inman, 1976).

The total sand input to the Santa Barbara Littoral Cell at Mandalay Beach is estimated to be 1,230,000 yd^3/yr (941,000 m^3/yr) (Inman, 1976). The rate at which this sand is being transported through the cell at Mandalay Beach is estimated by determining sand entrapment at Channel Islands Harbor. Periodically the sand is dredged from the sand trap and bypasses the Harbor. Since its construction in 1960, the trap has been dredged once every two years with removal of about 2,500,000 yd^3 (1,910,000 m^3). Thus, the longshore transport rate at Mandalay Beach is 1,250,000 yd^3/yr (946,000 m^3/yr). Therefore, the quantities of sand being supplied to the cell almost exactly balance the longshore transport and ultimate losses from the cell, down the Hueneme Submarine Canyon (Inman, 1976).

Since the budget of sediment is now in close balance at Mandalay Beach, the sediment that does reach the coast is just adequate to meet the wave energy demand for longshore transport without any surplus to cause beach accretion. Thus, when periods of storm waves occur, the beach is eroded. The eroded beach sand moves offshore from the beach as it forms large bars at -10 to -20 feet (3.2 to 6.1 m) MLLW, where it begins its gradual migration back up onto the beach during the following summer season. This appears to be the present situation at Mandalay Beach where the beach seems to sustain a stable position under normal and long-term conditions, but undergoes temporary beach erosion episodes with the periodic occurrence of high waves.

7.0 DATA SOURCES

7.1 REPORTS

Coastal and nearshore changes in the Mandalay Beach region have been assessed in a number of studies by USACOE (1957, 1979, 1980, 1986). National Oceanic and Atmospheric Administration (NOAA) Maps for 1933 and 1977 were obtained from the USACOE, Los Angeles District (Shak, 2000), and from Noble (1989).

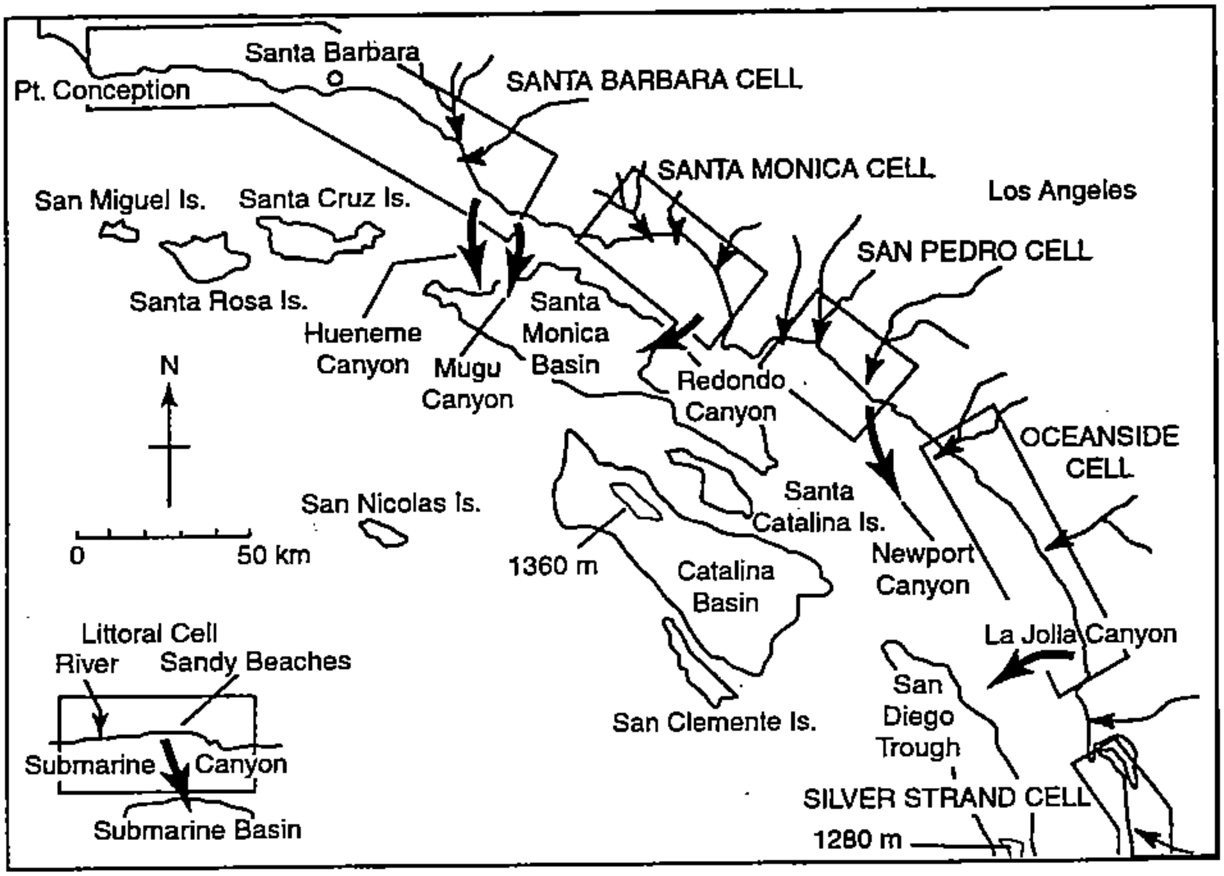

Figure 7. Southern California Littoral Cell, from Inman (1976).

7.2 HISTORICAL SURVEY DATA

7.2.1 USACOE Beach Erosion Studies

The Ventura County coastline has been hydrographically surveyed (nearshore and offshore bathymetry contour surveys) by the: 1) NOAA in 1933 and 1977; and 2) USACOE periodically since 1965. Mandalay Beach and nearby Oxnard Shores Beach were surveyed extensively in 1966 and again in 1977 by the USACOE. Both beaches showed a similar pattern of erosion in the shallower contours and accretion in the deeper contours. The Mandalay Beach area showed the greatest variance in comparison to the previous contours. Over the 11-year period, July 1966 to July 1977, the contours revealed a slight increase in accretion offshore and onshore.

7.2.2 BEACON Beach Profile Data (Noble, 1989)

In 1987, BEACON (Beach Erosion Authority for Coastal Operations and Nourishment) engaged Coastal Frontiers Corporation to establish 25 shore-perpendicular transects for the purpose of documenting changes in nearshore morphology along the coastline of Santa Barbara and Ventura Counties. Seven more transects were added in 1994 to facilitate monitoring of delta formation and dispersion near the mouth of the Santa Clara River. Survey data were acquired by Coastal Frontiers on five occasions: October 1987, April 1988, December 1992, September 1994, and October 1997.

Three BEACON transects were selected for use in this study (Transect 19, Delta Transect 07, and Transect 20). As illustrated in Figure 8, Transect 19 lies 8,300 ft (2,530 m) to the northwest of the pipeline alignment, Delta Transect 07 lies 1,100 ft (335 m) to the northwest, and Transect 20 lies 2,900 ft (884 m) to the southeast. The proximity and bracketing configuration of the transects, coupled with the linear nature of the coastline, suggest that the beach and nearshore changes recorded at these locations are indicative of those occurring on the pipeline alignment.

7.2.3 NOAA Bathymetry

To extend the historical database, digital files containing bathymetric survey data acquired by the NOAA in 1933 and 1977 were obtained from the USACOE, Los Angeles District (Shak, 2000). The NOAA data was used to construct a digital terrain map (DTM) of the project area, after which profiles were generated along the pipeline alignment and along the three BEACON transects.

7.3 RECENT SURVEYS

EcoSystems Management Associates conducted bathymetry, side-scan, sub-bottom sonar, and magnetometer surveys in the vicinity of the Mandalay marine pipeline in February and March of 2000 (EcoSystems, 2000). Also, on April 26 and 27, 2000 a beach profile survey at four ranges was conducted by Coastal Frontiers (2000) per Coastal Environments request.

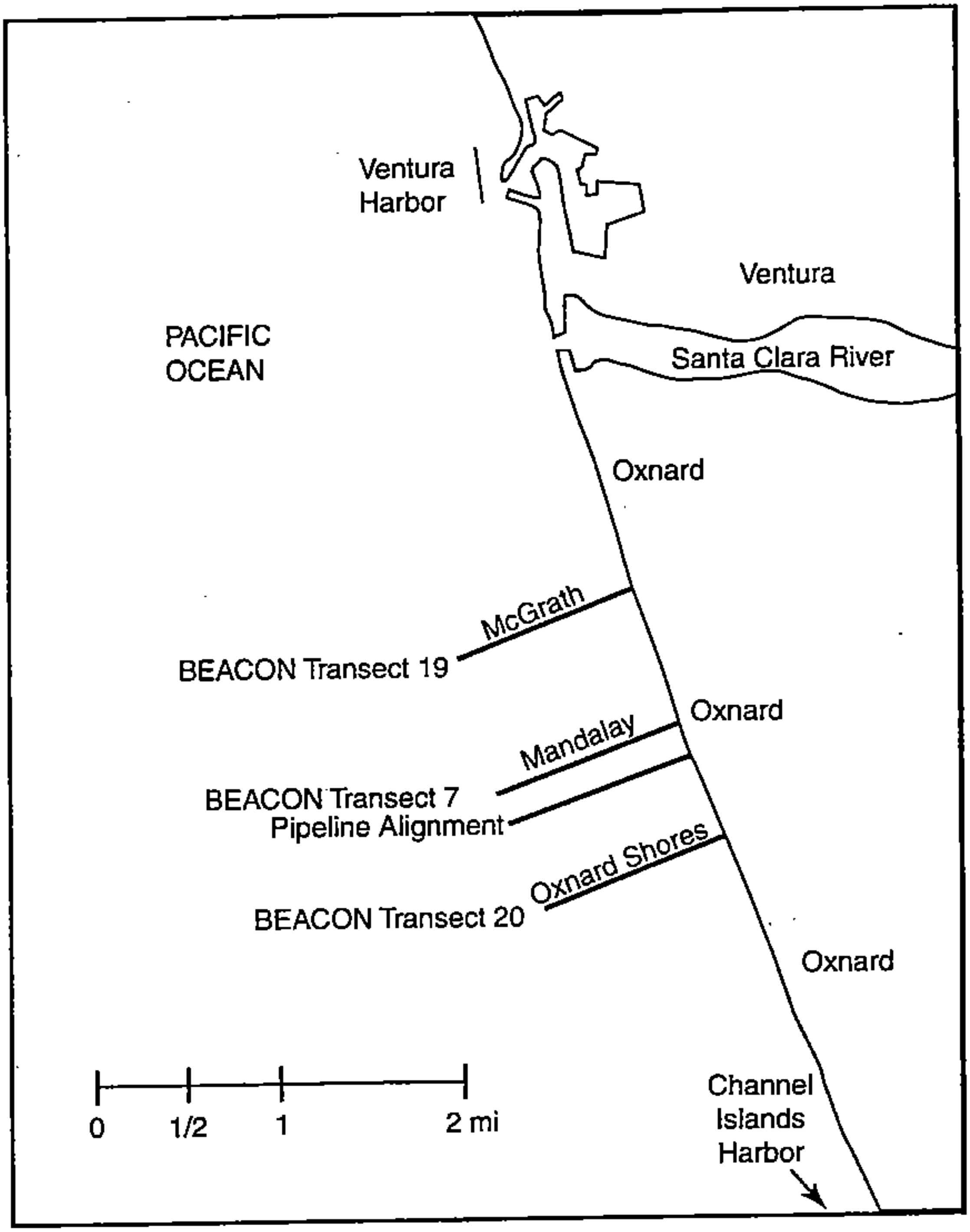

Figure 8. Beach profile locations.

8.0 BEACH PROFILES AND BATHYMETRY CHANGES

For the purposes of this study, primary emphasis was placed upon four beach profiles located near the study area. Three of these beach profiles were established in 1987 (Noble, 1989). In addition, a fourth transect was established along the Mandalay marine pipeline route itself on April 26 and 27, 2000. Figure 8 shows the locations of these profiles.

The historical and recent beach and bottom profile survey data are presented in Figures 9 through 12. In the case of Figures 9, 10, and 11, which pertain to BEACON Transects 19, Delta 7, and 20, the profiles derived from all relevant BEACON surveys and the two NOAA surveys are superimposed on the profile obtained in April 2000. In the case of Figure 12, which portrays the pipeline alignment, the April 2000 profile is shown with those derived from EcoSystems Management's February-March 2000 survey and the two NOAA surveys. The horizontal distances are measured from the survey origin (monument) along the transect alignment, while the elevations are measured from MLLW. Bathymetric changes along these four profiles are discussed below.

8.1 SHORELINE CHANGES

Inspection of Figures 9 through 11 reveals that, with the exception of BEACON Transect 19, the NOAA profiles from 1977 tend to evidence erosion relative to those from 1933. Although the cause of this apparent erosion can only be speculated upon, possible explanations include a lack of sediment input from the Santa Clara River, transient effects from the construction of Ventura Harbor, and less accurate data from the 1933 survey. Regardless of the cause, the apparent erosion was reversed during the subsequent period covered by the BEACON and present-day surveys. At all four transect locations, the profiles acquired since 1987 (including those from April 2000) lie at or above the elevations of the NOAA profiles. Furthermore, the April 2000 profiles tend to be shallower than the earlier BEACON profiles seaward of the berm-bar region (i.e., in depths greater than about -15 ft). Hence, during the past 12.5 years, the shoreline defined as the distance between the monument to the MLLW has been characterized by stability or modest accretion. Successive MLLW shoreline positions and shoreline position changes for the three BEACON transects are summarized in Table 1. Because historical survey data above MLLW are lacking along the pipeline alignment, similar shoreline comparisons cannot be developed for this location. The data in Table 1 suggest that despite short-term fluctuations, which can exceed 200 ft, the MLLW shoreline in the study area has remained stable or advanced during the 12.5-year period encompassed by the BEACON surveys. A first indication of the long-term trend is provided by computing the net change during the 12-year period between April 1988 and April 2000 (thereby minimizing the influence of seasonal fluctuations). As displayed in the last line of the table, the shoreline advanced by 168 ft at Transect 19, and by 204 ft at Transect 20. Although survey data from April 1988 is lacking on Transect Delta 7, the profiles acquired in September 1994, October 1997, and April 2000 suggest a similar trend toward accretion.

Historical aerial photographs were used by the USACOE for comparison of shoreline changes and to assess beach erosion. A 1929 photograph of Mandalay Beach was available from the Fairchild Collection, and a 1974 photograph was available from the Los Angeles District files.

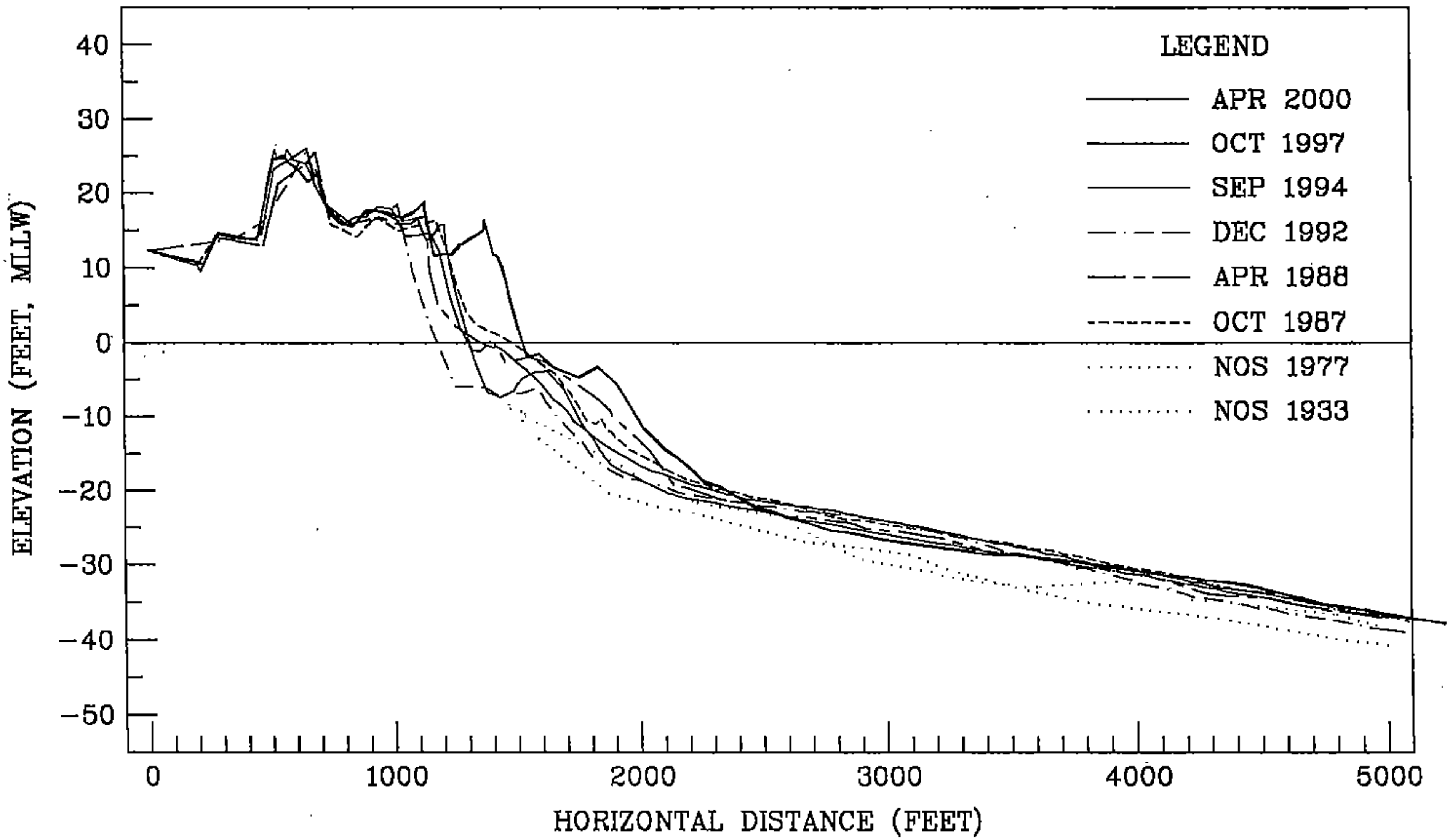

Figure 9. BEACON Transect 19, McGrath State Beach.

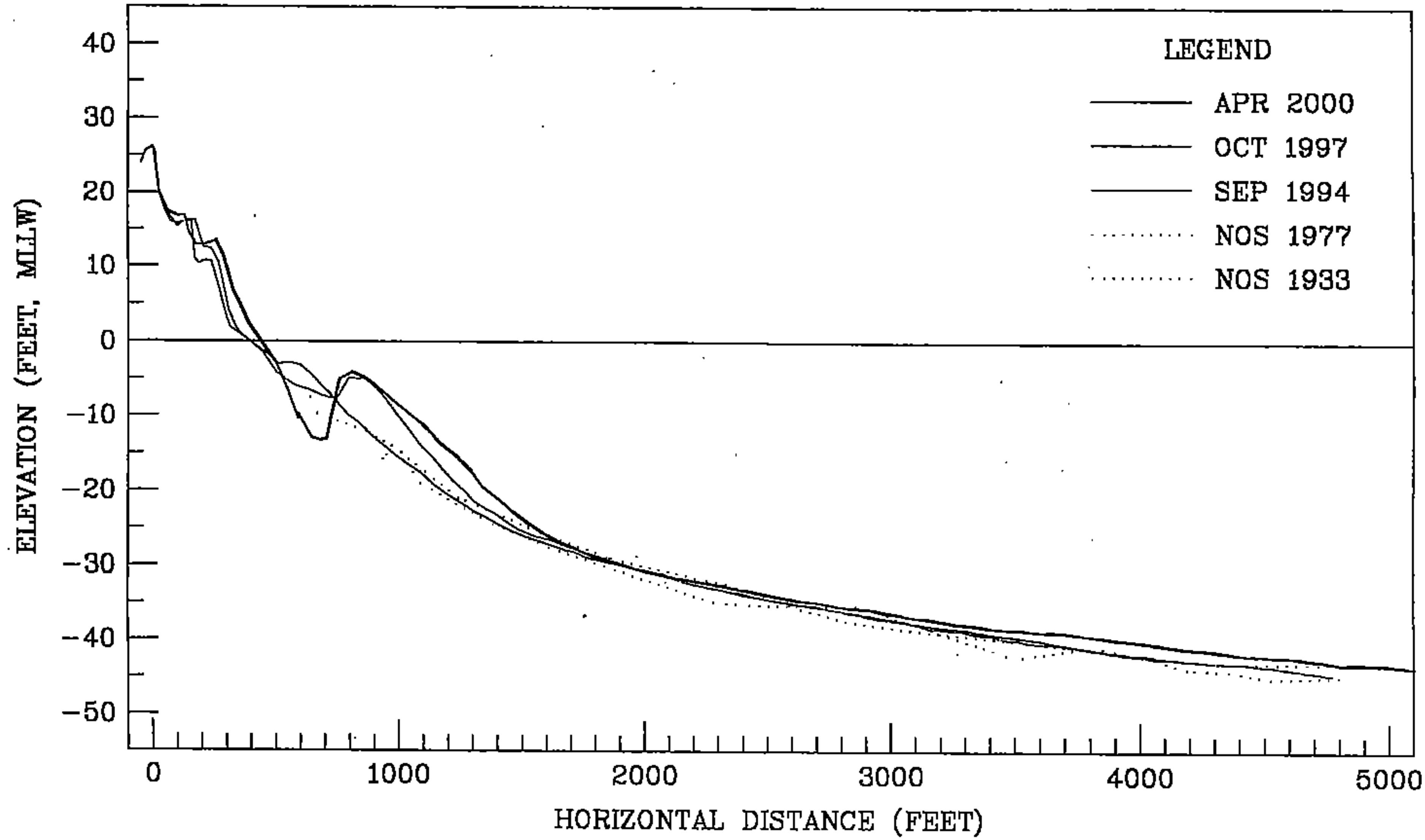

Figure 10. BEACON Delta Transect 7, Mandalay Beach.

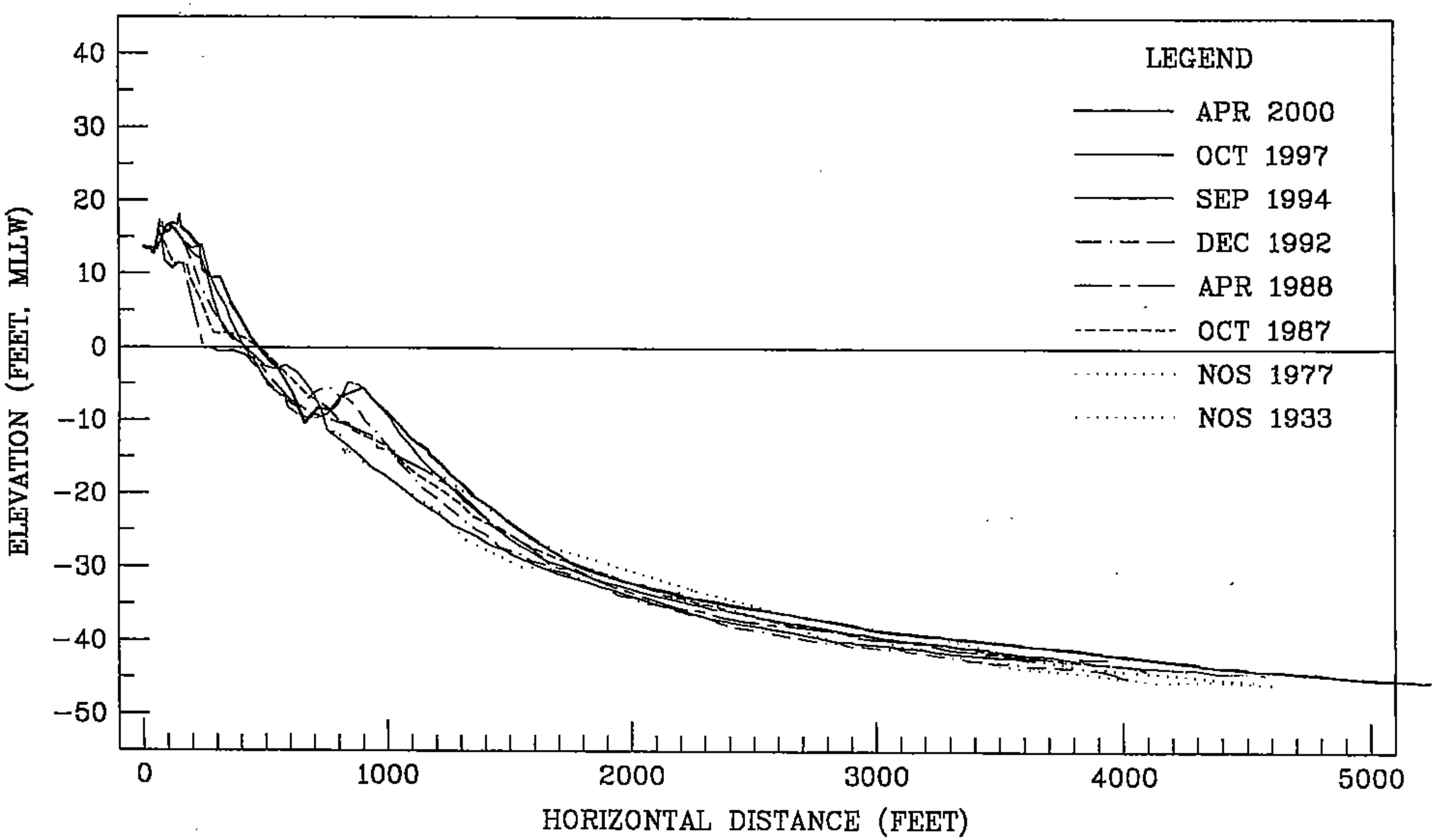

Figure 11. BEACON Transect 20, Oxnard Shores.

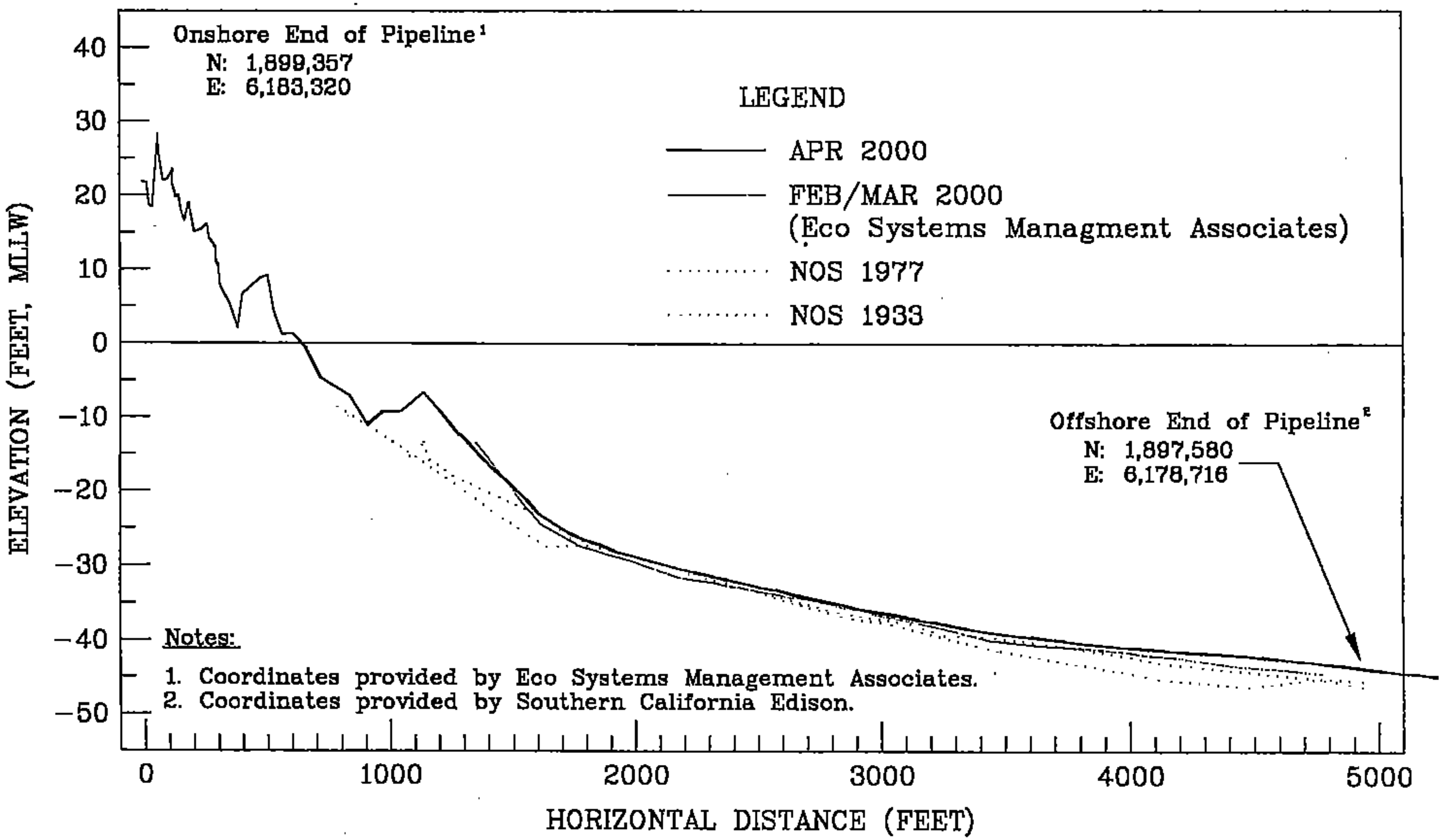

Figure 12. Pipeline Alignment, Mandalay Generating Station.

Table 1. MLLW Shoreline Positions at BEACON Transect Locations.

Date	Distance from Survey Monument/ Shoreline Change					
	BEACON 19 (McGrath)		BEACON Delta 7 (Mandalay)		BEACON 20 (Oxnard Shores)	
	Distance (ft)	Change (ft)	Distance (ft)	Change (ft)	Distance (ft)	Change (ft)
Oct-87	1478		--		469	
		-125				-200
Apr-88	1353		--		269	
		-181				124
Dec-92	1172		--		393	
		223				26
Sep-94	1395		362		419	
		-88		34		-6
Oct-97	1307		396		413	
		214		45		60
Apr-00	1521		441		473	
Net Change, Apr '88-Apr '00		168		n/a		204

Shoreline erosion rates for Mandalay Beach and Oxnard Shores Beach were estimated at 1.5 and 0.8 feet per year. respectively. This results are rough since estimating the shoreline position from aerial photographs has it is limitation due the difficulty of defining the shoreline.

8.2 BATHYMETRIC CHANGES

Additional insight into bathymetric changes is provided by Figures 13, 14, and 15, which display the envelope (maximum and minimum) and standard deviation of elevations measured from the first BEACON survey through the April 2000 field effort. At Transect 19 (McGrath State Beach, Figure 13), the envelope of elevation narrows to approximately 2 ft and the standard deviation decreases to approximately 1 ft in water depths exceeding 35 ft. At Transect Delta 7, which is located near the pipeline alignment, and Transect 20 (Oxnard Shores), comparable reductions in the elevation difference between maximum and minimum envelopes and elevation standard deviation occur in depths greater than 30 ft. This water depth is defined as the closure depth (Inman et al, 1993), the depth at which variations in sea bottom elevations between many years of beach profiles are small (standard deviation < 1ft, Figures 14).

Figure 16 shows a comparison between three bathymetry surveys made offshore of Mandalay Generating Station. The surveys were made by USACOE in 1966 and 1977 and by EcoSystems Management Associates in March of 2000. The differences for both the 30 ft and 36 ft contours were about ±2 ft.

9.0 CONCLUSIONS

This study presents assessment of bathymetry changes that have occurred at Mandalay Beach. The study is based on historical beach and bathymetric studies, as well as recent bathymetry and beach profile surveys made in February, March, and April 2000, respectively.

Seasonal and inter-annual fluctuations in the Mandalay Beach mean-lower-low-water (MLLW) shoreline position can exceed 200 feet (61 m) in the vicinity of the pipeline alignment. The long-term trend of the shoreline position at Mandalay Beach has been one of slight erosion from 1933 to 1977 and one of stability or modest advancement since 1987. The winter profile bar in the Mandalay Beach area can experience dramatic changes in its position due to the winter storms that periodically sweep into the area. However, the elevation changes in the offshore portion of the beach profile at water depth 30 ft or greater are small. Based on beach profile data from 1933 to April 2000 (Figures 10, 12, and 14) and three bathymetric surveys made in 1966, 1977 and 2000 (Figure 16), the estimated depth changes at distances of 1800 ft from the shoreline or greater are small (≤ 2 ft).

Based on bathymetric changes over the past 67 years, one can predict future bottom elevation changes with reasonable confidence. The offshore area beyond 2000 feet (610 m) from the shoreline is estimated to have varied 2 to 3 ft (0.6-0.9 m) from the present sea bottom. This information indicates that the offshore portion of the pipeline beyond 1800 ft (548 m) from the shoreline and the associated anchors and anchor blocks will remain buried.

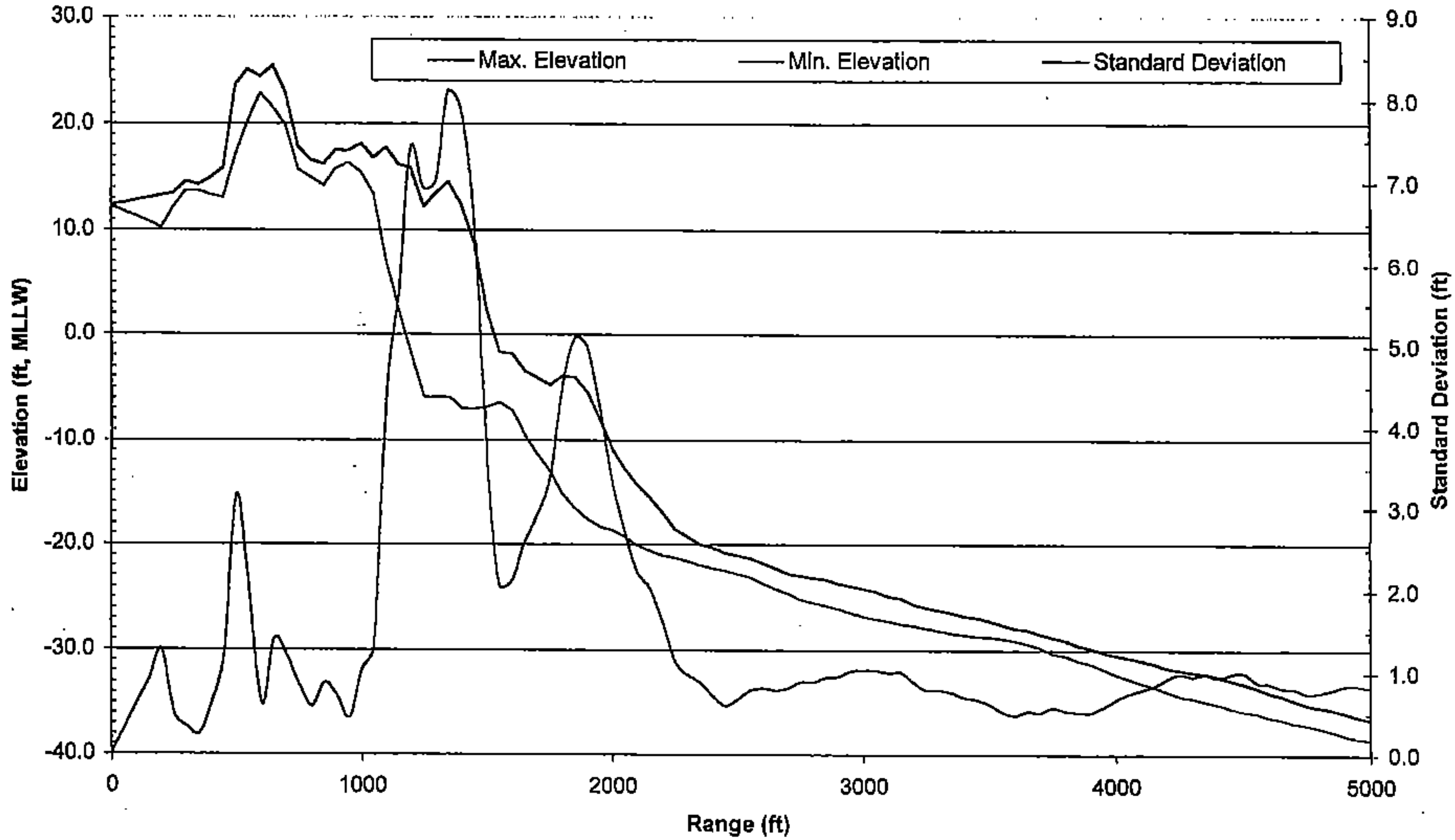

Figure 13. Envelope and standard deviation of beach profile elevations, BEACON Transect 19 (1987-2000).

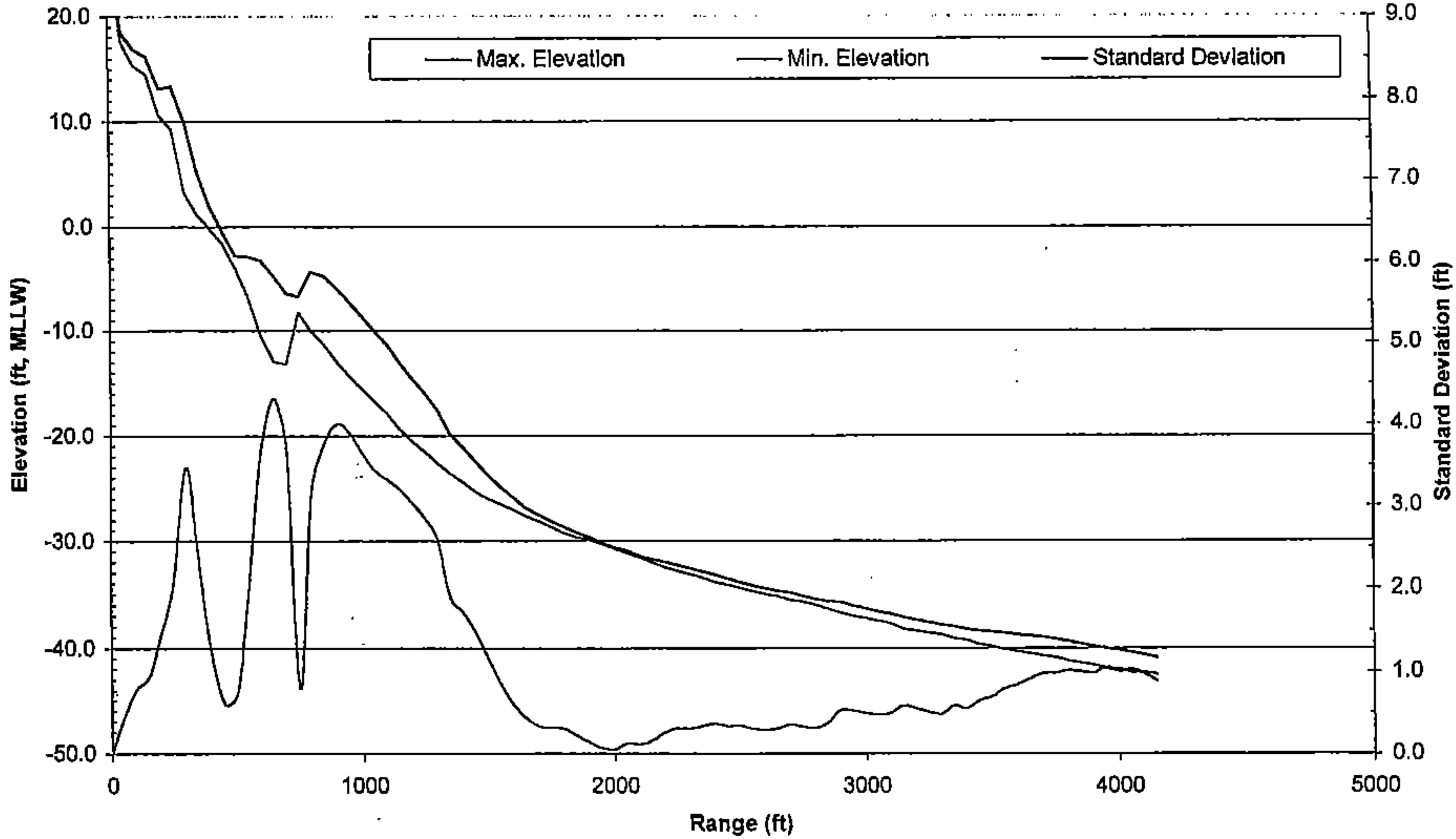

Figure 14. Envelope and standard deviation of beach profile elevations, BEACON Delta Transect 7 (1994-2000).

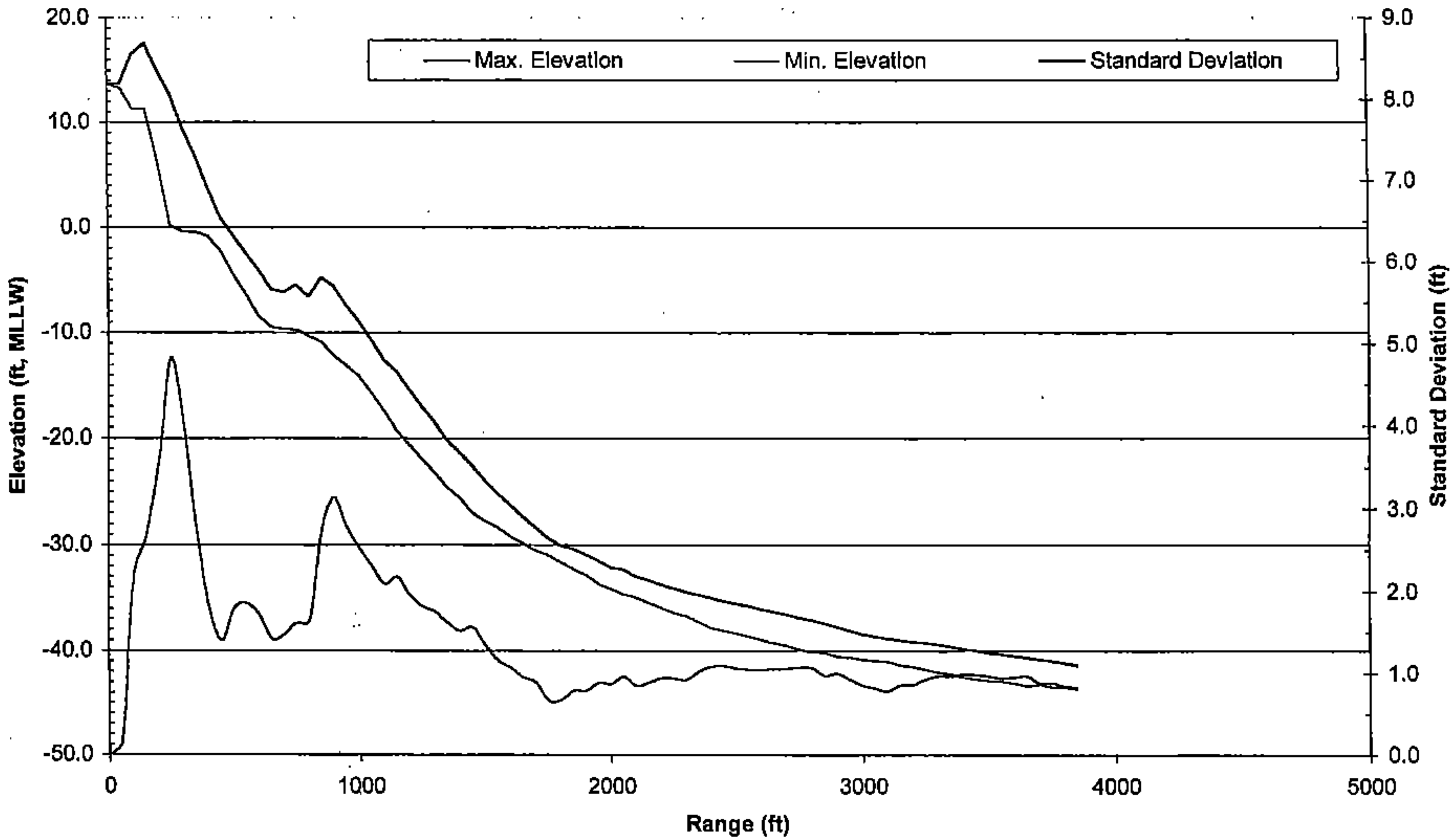

Figure 15. Envelope and standard deviation of beach profile elevations, BEACON Transect 20 (1987-2000).

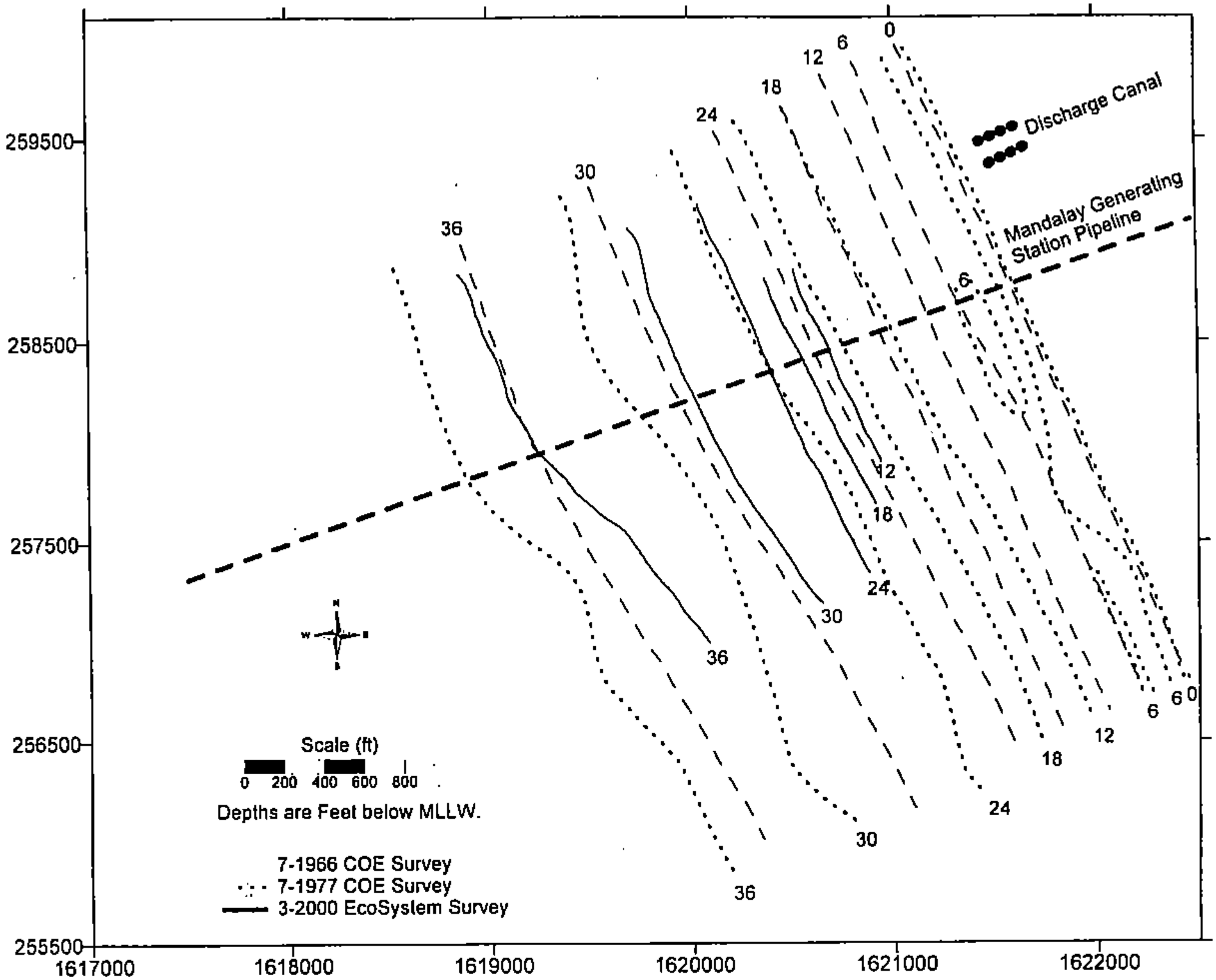

Figure 16. Comparison between 1966, 1977, and 2000 bathymetry surveys offshore Mandalay Beach.

10.0 ACKNOWLEDGEMENTS

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APPENDIX A

APRIL 26-27, 2000 BEACH PROFILING METHODOLOGY

April 26-27, 2000 Beach Profiling Methodology

A standard technique for beach profiling was used during the April 26-27, 2000 beach survey. The method is similar to methods employed during the most recent BEACON field program (Hearon, 1997), and consisted of two primary components: a wading survey and a vessel-based bathymetric survey.

The wading survey was conducted by a two-person crew using an electronic distance meter (EDM) and conventional survey techniques. Range and elevation data for each point surveyed were stored on a data logger for subsequent transfer to a computer for processing. The data were acquired in the following manner:

* The benchmark for a given transect was located;
* Markers were set along the transect alignment using a magnetic compass;
* The EDM was set up either over the benchmark, or on the transect alignment;
* A rod man walked or swam along the transect, using the markers for alignment, holding a survey rod vertically erect on the ground at intervals of approximately 50 feet (or less if abrupt elevation changes or breaks in slope were encountered); and
* A surveyor, using the EDM, recorded the range, bearing, and difference in elevation at each occupied point.

Each transect was surveyed from the backbeach seaward through the surf zone until the submersible survey rod no longer protruded above the water surface when held erect. This location, which corresponded to a water depth of 11 to 13 ft below MLLW for an average tide height of 2 ft, provided substantial overlap with the landward portion of the bathymetric survey.

The EDM used to conduct the wading survey is capable of measuring ranges to within 0.5 ft and elevation differences to within 0.1 ft. However, because each of the three BEACON transects was established using a magnetic compass, the horizontal accuracy measured normal to the transect (parallel to the shoreline) varied from minimal at shore ranges to approximately 15 ft at the offshore end.

The bathymetric survey was conducted from a 16-ft inflatable survey vessel. Soundings were obtained at 10 second intervals, corresponding to a distance of approximately 70 ft, using a Raytheon DE-719C acoustic fathometer. The position of each sounding was determined with a Trimble Pathfinder Pro XR GPS receiver, which utilizes a network of navigational satellites maintained by the U.S. Government. To improve the accuracy of each fix, differential position corrections transmitted in real time from U.S. Coast Guard beacons were utilized. Based on the specifications issued by the equipment manufacturer, the root mean square (rms) accuracy of DGPS positions obtained in this manner is less than 3.3 ft (1 m).

The bathymetric data were collected in the following manner:

* Using the GPS unit, the survey boat was maneuvered to the offshore end of the transect;

* The survey boat proceeded toward shore using GPS navigation for guidance;
* A continuous trace of the seafloor was recorded on the fathometer;
* DGPS position data were logged every 10 seconds;
* A "fix mark" was recorded on the fathometer trace simultaneous with the recording of the DGPS position data;
* The time of each fix was noted on the fathometer trace to allow for correlation of the soundings with the position data; and
* The data collection continued until landward progress was precluded by breaking waves.

The fathometer was calibrated using a technique known as a "bar check," in which an acoustically reflective grate was suspended beneath the echo sounder transducer at depths of 10, 20, 30, and 40 feet. For each of these known depths, the difference between the bar depth and the fathometer readout was noted. These differences were used to develop a correction algorithm that was applied to the bathymetric data subsequent to the survey. A bar check was conducted at the beginning and end of each survey line.

The data from the wading survey were processed using proprietary software developed by Eagle Point Software Corporation. The raw EDM data were read by the Eagle Point software, and the coordinates and elevation of each data point were calculated and inserted into an AutoCAD drawing.

The bathymetric data obtained along each transect were processed in the following manner:

* A line was faired through the fathometer trace to minimize the influence of wave contamination;
* The faired line was digitized at each fix mark;
* The raw, digitized soundings were corrected using the calibration algorithm determined from the bar checks;
* The corrected soundings were adjusted to MLLW datum using water level data recorded by the National Ocean Service (NOS) tide gauge in Los Angeles Harbor;
* The adjusted soundings were merged with the corresponding DGPS horizontal position data on the basis of time;
* The resulting x, y, z data (northing, easting, and elevation) were inserted into the AutoCAD drawing containing the wading data; and
* The Eagle Point software was used to calculate the range and elevation of each point along the transect.

It should be noted that the bathymetric data acquired during the prior BEACON surveys had been adjusted to MLLW datum using an NOS tide gauge located in Santa Barbara. This gauge was decommissioned in 1998, however, necessitating the use of the Los Angeles Harbor gauge. To minimize the impact of the change, the water levels recorded in Los Angeles were adjusted to the Santa Barbara site using the time and height differences published by NOAA. Nevertheless, discrepancies of up to 0.25 ft may have resulted from the use of the more distant tide gauge. The accuracy of the corrected, tide-adjusted soundings is estimated to be ±0.6 ft.

As indicated above, the field work was conducted in such a manner as to provide overlap between the wading and bathymetric portions of the survey. The processed data were examined in this region to insure that the two data sets were compatible. Once this confirmatory inspection had been completed, the data were merged and the bathymetric data were purged from the region of overlap in favor of the inherently more accurate wading data. The resulting range and elevation data then were used to create continuous beach profile plots.